THE CONTROL OF CHOICE BY ITS CONSEQUENCES

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Five pigeons were trained on concurrent variable-interval schedules in which equal rates of reinforcement were always arranged for left- and right-key responses, but different overall rates were signaled by key colors. Sessions began with both keys lit yellow for the instrumental phase. If, after 20 s of this phase, the relative number of responses that had been made to the left key equaled or exceeded .75, both keys changed red for the contingent phase. The contingent phase arranged another concurrent variable-interval schedule for a further 20 s before the instrumental phase was reinstated. However, if preference in the instrumental phase did not exceed .75, the instrumental phase continued for a further 20 s before preference was again compared with the criterion. In Part 1, the reinforcer rate arranged in the instrumental phase was held constant at 4.8 reinforcers per minute, while the reinforcer rate arranged in the contingent phase was varied across conditions from 0 to 19.2 over five steps. In Part 2, reinforcer rates in the contingent phase were kept constant at 36 per minute, while reinforcer rates in the instrumental phase were varied from 0 to 36 over seven steps. Part 3 replicated Part 2 but used reinforcer rates in both phases that were one third of those arranged in Part 2. Measures of choice obtained by summing responses across presentations of the instrumental phase became more extreme toward the left key as the reinforcer rate obtained in the contingent phase was increased (Part 1) and as the reinforcer rate obtained in the instrumental phase was decreased (Parts 2 and 3). Changes in these measures of choice were accompanied by systematic changes in the relative frequency with which the criterion was exceeded. Changes in both these measures were correlated with changes in the relative frequency with which subjects responded exclusively to the left key. These results are discussed with respect to the two choices that were concurrently available in this procedure and the response alternatives that might constitute the concurrent operants in each choice.

Key words: choice, concurrent variable-interval schedules, reinforcer rates, behavioral units, pecking, pigeons

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Research investigating how an animal will choose between emitting different responses has a long history in the experimental analysis of behavior. With respect to choices between responses maintained by positive reinforcement, studies of performance on concurrent variable-interval variable-interval (VI VI) schedules have shown a number of reinforcer parameters to be important. For example, the relative frequency with which either response is reinforced (Herrnstein, 1961), the relative magnitude of either reinforcer (Schneider, 1973), and the relative delay until either reinforcer is obtained (Chung & Herrnstein, 1967) control, to varying ex-

tents, the relative frequency with which either response is emitted.

In the majority of studies that have investigated concurrent VI VI performance, the degree of preference that an animal shows for one alternative has little or no systematic effect on the production of consequences. That is, the function relating the rate, magnitude, or delay until reinforcers to the relative frequency of either response is generally flat, so that the measure of preference obtained can be taken to indicate only the relative reinforcing effects of the two schedules. Indeed, when this function is not flat, and relative choice does partly determine parameters of the reinforcers obtained, the experiment is often seen as confounded, because numerous controlling variables might be identified. The present experiment investigated how one consequence of some degree of choice, namely the overall rate of reinforcement produced by that choice, might function as a variable controlling that choice.

Previous attempts to investigate empirically the control of choice by overall reinforcer

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rates have met with mixed results. For example, Davison and Kerr (1989) investigated the choice behavior of pigeons in conditions that arranged concurrent VI VI schedules in combination with mathematical algorithms known as feedback functions. These feedback functions related the overall rate of reinforcement in a current time window to the degree of preference in a prior time window. The duration of a window was fixed and constant within conditions, and the transition between windows was not signaled in any manner. In Phase 2 of their Experiment 1, relative rates of reinforcement were varied across conditions, and the overall rate of reinforcement in each condition progressively decreased the more that relative time allocation since the prior reinforcer deviated from .5. In Phase 3, reinforcer ratios were again varied, but overall rates of reinforcement now increased the more that relative time allocation deviated from .5. Davison and Kerr reasoned that if relative choice could be controlled by overall reinforcer rates, then preference in each condition should be biased toward areas of the feedback function providing higher overall reinforcer rates. Consequently, across conditions, the sensitivity of changes in time-allocation ratios to changes in obtained reinforcer ratios should be lower in Phase 2 than in Phase 3. Failing to find such a difference led them to conclude that the contingency between choice and overall reinforcer rate exerted little or no control over relative choice.

A similar conclusion was reached by Vaughan (1981). Vaughan arranged concurrent VI VI schedules and feedback functions in which pigeons' relative time allocation in an unsignaled 4-min window determined both the relative and overall rates of reinforcement in the subsequent unsignaled 4-min window. In Condition b of his experiment, he found that preference stabilized in a part of the feedback function where local rates of reinforcement for the two responses were equal but overall rates of reinforcement were at their lowest (see Vaughan's Figures 1 and 2). Vaughan argued that these results were incompatible with the notion that matching in concurrent VI VI schedules is an indirect result of a reinforcement-rate maximization process (e.g., Rachlin, Green, Kagel, & Battalio, 1976; Staddon & Motheral, 1978;

but see Shimp, 1969, for discussion of a more molecular maximizing process).

Other studies, however, have shown that under different procedural conditions, relative choice in one time window can be affected by contingent changes in the overall or relative rate of reinforcement in a subsequent period. One such study was by Silberberg and Ziriax (1985). These authors also arranged fixed and constant time windows, and did not signal transitions from one window to the next. However, rather than using feedback functions to change overall and relative reinforcer rates in a continuous manner, they arranged only one (and sometimes two) pair of contingencies to determine a later reinforcer rate depending on current choice. Consider, for example, Conditions 2 and 7 of their study. In both conditions, if the subject's relative time spent responding on the right key in the previous time window was greater than .25, the next window arranged equal concurrent VI VI schedules that could provide 30 reinforcers per hour. If, on the other hand, relative right-key time allocation in the previous window was less than .25, then the next window arranged 30 reinforcers per hour from the left key but 240 per hour from the right key. Thus, overall reinforcer rates could be increased if relative choice was biased in a direction opposite to that predicted by the matching of relative time allocations to the relative rates of reinforcement. Silberberg and Ziriax reported that in conditions arranging the 6-s window, the times allocated to the two alternatives were relatively insensitive to changes in the obtained relative reinforcer rates, but were such that they maximized local rates of reinforcement. However, when window durations were 240 s, their results replicated those of Vaughan (1981) and indicated little control of choice by overall reinforcer rates.

Davison and Alsop (1991) arranged a procedure similar to that arranged by Silberberg and Ziriax (1985) and reported similar results. Davison and Alsop arranged equal concurrent VI VI schedules and, in one set of conditions (their *dependent* procedure), a single pair of contingencies to determine the overall and relative rates of reinforcement in a subsequent time window depending on relative choice during a prior window. Specifically, following every fixed period of time, the

relative number of responses that had been emitted on the left key in the prior window was calculated, and if this value exceeded .75, the number of reinforcers per hour obtainable on the right key in the next window increased from approximately 11 (i.e., equal to the number obtainable from the left key) to approximately 600. However, if this measure of relative choice was less than .75, the initial VI schedules remained operative and relative choice was again evaluated after the next window duration had elapsed. The control of choice by these contingencies was apparent only when window durations were less than 30 s. Thus, despite scheduling considerably more reinforcers for right-key responses when greater than 75% of responses were to the left key, the increase in overall reinforcer rates that occurred when this criterion was met was effective in biasing choice to the left key. This bias was assessed relative to control conditions that arranged similar but behavior-independent reinforcer-rate changes (see their Figure 2).

Silberberg and Ziriax (1985) argued that Vaughan's failure to see evidence of control by overall rates of reinforcement was likely to have resulted from his use of 4-min windows. They argued that "this period is well beyond extant demonstrations of pigeon memory for prior choices and their consequences," and "a pigeon cannot maximize its choice allocations when it cannot recall these key events" (p. 85). Indeed, Silberberg and Ziriax reported control of choice by overall reinforcer rates only when window durations were short (6 s), and Davison and Alsop found that the degree of this control decreased systematically as window durations increased. However, the window over which relative choice is measured cannot alone determine the efficacy of these contingencies, because Davison and Kerr (1989, Experiment 2) arranged two window durations (5 s and 20 s) that were in a range similar to those used by Silberberg and Ziriax and by Davison and Alsop, but failed to see evidence of contingency control.

Heyman and Tanz (1995) advanced an alternative explanation for why changes in overall reinforcer rates contingent on choice have often exerted little or no control of that choice. They argued that relative rates of reinforcement, rather than overall rates, often better control choice, because the rates of reinforcement obtained for either response are always signaled by exteroceptive stimuli (e.g., left vs. right response keys) whereas overall rates of reinforcement are not. In support of this argument, Heyman and Tanz explicitly signaled the satisfaction of a choice criterion and a consequent change in the overall rate of reinforcement (by a change in the color of a houselight), and reported the effectiveness of the contingencies to be greatly enhanced. In both their Experiments 1 and 2, the proportion of responses made to one of two keys was calculated after some fixed number of responses had occurred, and reinforcement was contingent upon responses that produced response proportions that differed from the nominal reinforcer proportions by some deviation criterion. Although response proportions generally deviated further from reinforcement proportions as the deviation criterion increased, when satisfaction of the deviation criterion was not signaled (Experiment 1), response proportions did not move more than $\pm.2$ from the relative rate of reinforcement. In contrast, there seemed to be no limit to the deviations from matching that could be obtained when discriminative stimuli signaled satisfaction of the deviation criterion (Experiment 2).

The results reported by Heyman and Tanz (1995) suggest that previous failures to show control of choice by overall rates of reinforcement may have resulted from a subject's failure to discriminate changes in these reinforcer rates across two time intervals. However, it is likely that the effectiveness of these contingencies will also depend on the actual reinforcer rates obtained when choice does, and when choice does not, exceed some criterion, even when discriminative stimuli signal these changes.

The present experiment can be viewed as an extension of Heyman and Tanz's (1995) study, with a view to determining the effects of various signaled changes in overall reinforcer rates following satisfaction of some criterion measure of choice. It is, essentially, a "bottom-up" approach towards the complex procedures arranged by Vaughan (1981), Silberberg and Ziriax (1985), and Davison and Kerr (1989). In the present study, unlike these earlier studies, the window over which relative choice was measured (the instrumental phase) and the window over which reinforcer rates

dependent on that choice operated (the contingent phase) never overlapped and were each signaled by distinct exteroceptive stimuli. When a specific choice criterion had been met in an instrumental phase, a change in the overall rate of reinforcement in the contingent phase was signaled by a change of key colors. If the criterion had not been met, the instrumental phase was presented again and choice was assessed after the next fixed window. These modifications were intended to permit an assessment of the effects of absolute rates of reinforcement in this paradigm. Specifically, in all conditions, the relative rate of reinforcement for left- and right-key responses in each phase was kept constant and equal, but the overall rates of reinforcement in each phase were varied across conditions. In this way, the effect of various choice-dependent changes in overall rates of reinforcement was assessed by analyzing the degree to which relative rates of responding in the instrumental phase deviated from indifference and toward the value specified as the criterion. The primary question was: How did the rates of reinforcers obtained in the instrumental and contingent phases affect relative choice in the instrumental phase? Was a simple, positive difference between reinforcer rates obtained in the contingent and instrumental phases sufficient, did the degree of contingency control increase as this difference increased, or did control depend on the absolute reinforcer rates in either phase? Assuming that some change in relative choice would be observed across conditions, we were also interested in the nature of this change at a more molecular level. Specifically, we asked how the relative frequency of instrumental phases that contained various particular choice ratios changed across conditions. The general question is thus: How is choice affected by changes in overall rates of reinforcement that are contingent on specific values of that choice?

METHOD

Subjects

Five homing pigeons, numbered 11 through 15, were maintained at 85% of their free-feeding body weights by supplementary feeding of mixed grain following experimental sessions. Water and grit were freely available in the home cages. All of the birds, except Bird 13, had prior experience with concurrent VI VI schedules of reinforcement signaled by stimuli similar to those used here (see Davison & Alsop, 1991).

Apparatus

A lightproof and sound-attenuating experimental chamber (300 mm wide, 330 mm deep, and 330 mm high) contained an interface panel and an exhaust fan. Three horizontally aligned translucent response keys were mounted 260 mm above a wire grid floor on the interface panel. The keys were 20 mm in diameter and were set 70 mm apart, center to center. A minimum force of 0.1 N operated a microswitch mounted behind each key.

Only the two side keys were used in the present experiment. The center key remained dark and inoperative throughout. Both side keys could be illuminated yellow or red by lamps situated behind them. These stimuli were not equated for brightness. An aperture (50 mm wide by 50 mm high) was located directly below the center key and 130 mm from the floor. A solenoid-operated hopper delivered wheat through this aperture. Each presentation of the hopper was for 3 s and was accompanied by the illumination of the aperture and the extinction of all key stimuli. Key and hopper illumination were the only light sources in the chamber.

All experimental events were controlled and recorded by a personal computer running MED-PC® software. This computer was located in an adjoining room.

Procedure

Because 4 of the birds had prior experience with concurrent VI VI schedules, preliminary training was required only for Bird 13. This bird was trained to eat from the food magazine, then to peck a lit key for food presentations, and finally to obtain food from concurrent VI VI schedules arranged on two keys lit either both yellow or both red.

Experimental sessions were conducted daily for each bird. All sessions commenced and ended in chamber darkness, and lasted until 40 reinforcers had been obtained or until 45 min had elapsed, whichever occurred first.

Figure 1 illustrates the cyclical nature of the procedure that was arranged in each ses-
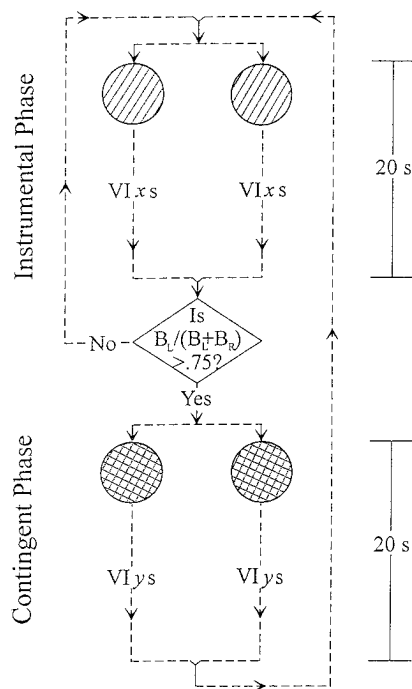
Fig. 1. A diagram of the general procedure arranged in the present experiment. All sessions began with two keys being lit yellow for the instrumental phase. Effective responses to left and right keys were reinforced according to equal concurrent VI VI schedules arranged dependently. After 20 s of this phase, the relative number of responses that had been emitted to the left key was calculated. If this measure exceeded .75, the two keys changed red and another concurrent VI VI schedule operated for a further 20 s before the instrumental phase was reinstated automatically. The VI schedules operating in the contingent phase also arranged equal rates of reinforcement. If relative choice during the instrumental phase did not exceed the .75 criterion, both keys remained yellow for a further 20 s until choice was again compared to the criterion.

sion. Sessions began with the two side keys lit yellow, designating the instrumental phase. Effective responses to either key during this phase were reinforced with food presentations according to equal concurrent VI VI schedules. These schedules were arranged dependently (Stubbs & Pliskoff, 1969) to insure that the obtained reinforcer ratio did not covary systematically with preference. In addition, a changeover delay (Herrnstein, 1961) was arranged so that at least 3 s had to elapse following a changeover before a response could be reinforced. Following 20 s in the instrumental phase, the proportion of total responses that the subject had made to the

left key was calculated. If this proportion was less than .75, the instrumental phase continued for a further 20 s before the relative rate of responding was again calculated. However, if the proportion of responses to the left key in the instrumental phase equaled or exceeded .75, both keys were immediately lit red to signal a 20-s contingent phase. Responses to either side key during this phase were also reinforced according to equal concurrent VI VI schedules arranged dependently and with a 3-s changeover delay operating, although the actual schedule values could differ from those that had been arranged in the instrumental phase. Each contingent phase was followed by an instrumental phase. The VI VI schedules operating during instrumental phases stopped timing during contingent phases, and those operating during contingent phases stopped timing during instrumental phases. However, reinforcers that were set up but not delivered for either response in either phase were held over until that phase was again presented. Thus, a reinforcer could be obtained after the first response to the designated key since the onset of a particular phase.

Table 1 shows the total number of reinforcers per minute that were arranged for responding on both keys during the instrumental and contingent phases in each condition of Parts 1, 2, and 3. Also shown is the number of training sessions that the birds received in each condition. Conditions have been numbered according to the order in which they were arranged. In Part 1, the arranged overall rate of reinforcers in the instrumental phase was held constant at 4.8 reinforcers per minute while the arranged overall rate of reinforcement in the contingent phase was varied from 0 to 24 over five steps. In Part 2, the arranged overall rate of reinforcement in the contingent phase was held constant at 36 reinforcers per minute while the overall rate of reinforcement arranged in the instrumental phase was varied from 0 to 36 over seven steps. The conditions in Part 3 arranged reinforcer rates in both phases that were approximately one third of those arranged in conditions of Part 2. That is, the arranged overall rate of reinforcement in the contingent phase was always 12 reinforcers per minute while the overall rate of reinforcement arranged in the instrumental phase was var-

Table 1

The total number of reinforcers per minute (rate) arranged for responses to the left key (and equally for responses to the right key) in the instrumental and contingent phases of each condition, and the number of training sessions in each condition. Conditions have been numbered according to the order in which they were run.

Part	Condition	Instrumental rate	Contingent rate	Number of sessions
1	1	2.40	0.0	19
	2	2.40	12.0	21
	3	2.40	1.2	23
	4	2.40	9.6	19
	5	2.40	2.4	18
	20	2.40	0.0	19
2	6	0.00	18.0	29
	7	2.40	18.0	24
	8	0.60	18.0	26
	9	4.80	18.0	25
	10	3.60	18.0	21
	11	6.00	18.0	23
	18	18.00	18.0	22
3	12	1.80	6.0	21
	13	0.18	6.0	25
	14	0.78	6.0	20
	15	0.00	6.0	25
	16	1.56	6.0	21
	17	1.20	6.0	22
	19	6.00	6.0	18
	21	0.00	6.0	22

ied from 0 to 12 over seven steps. Conditions 20 and 21 were replications of Conditions 1 and 15, respectively. These conditions were replicated because relative measures of choice in the instrumental phase of these conditions were generally the lowest (Condition 1) or the highest (Condition 15) across conditions.

Each condition remained in effect until the performance of all birds had met a stability criterion. This criterion was as follows. The proportion of total responses emitted to the left key in the instrumental phase was calculated for each bird after each session. Following 10 sessions in a condition, median response proportions over the last five sessions were calculated and compared with the median from the previous set of five nonoverlapping sessions. If these medians were within .05 of each other on five, not necessarily consecutive, occasions, the bird's performance was judged to be stable. Thus, a minimum of 14 sessions was required before responding in a condition could be considered stable.

Conditions were changed for all subjects only after each subject had satisfied this criterion.

The data collected from each session were the elapsed times since the start of the session until each experimental event (e.g., each response, reinforcer, and keylight change) occurred. Thus, time records were obtained for each left- and right-key response and reinforcer during the instrumental phase, each left- and right-key response and reinforcer during the contingent phase, each transition from the instrumental to the contingent phase, and each transition from the contingent to the instrumental phase.

RESULTS

Shown in the Appendix, for each condition, are the number of times that a subject entered an instrumental and a contingent phase (entries), the number of left- and right-key responses (B_L and B_R, respectively), the time spent responding on the left and right keys (T_L and T_R, respectively), and the number of reinforcers obtained for left- and right-key responses (R_L and R_R, respectively), during the instrumental and contingent phases. These data are the sums over the last five sessions of each condition and were those used in all analyses.

Relative Frequency of Left-Key Pecking in the Instrumental Phase

The first analysis of how responding was affected by the contingencies arranged here was in terms of the relation between overall measures of choice in the instrumental phase and the rates of reinforcement obtained in the instrumental and contingent phases. In this analysis, relative rates of left-key pecking in the instrumental phase of each condition were calculated from the number of left-key and right-key pecks summed across instrumental phases, and obtained rates of reinforcement were calculated by considering the number of reinforcers obtained in the time that a subject spent in the instrumental and contingent phases.

Figure 2 shows the relation between overall relative rates of left-key pecking and obtained reinforcer rates in either phase, for each subject in Parts 1, 2, and 3 separately. Recall that in Part 1 the rate of reinforcement arranged in the instrumental phase was held constant
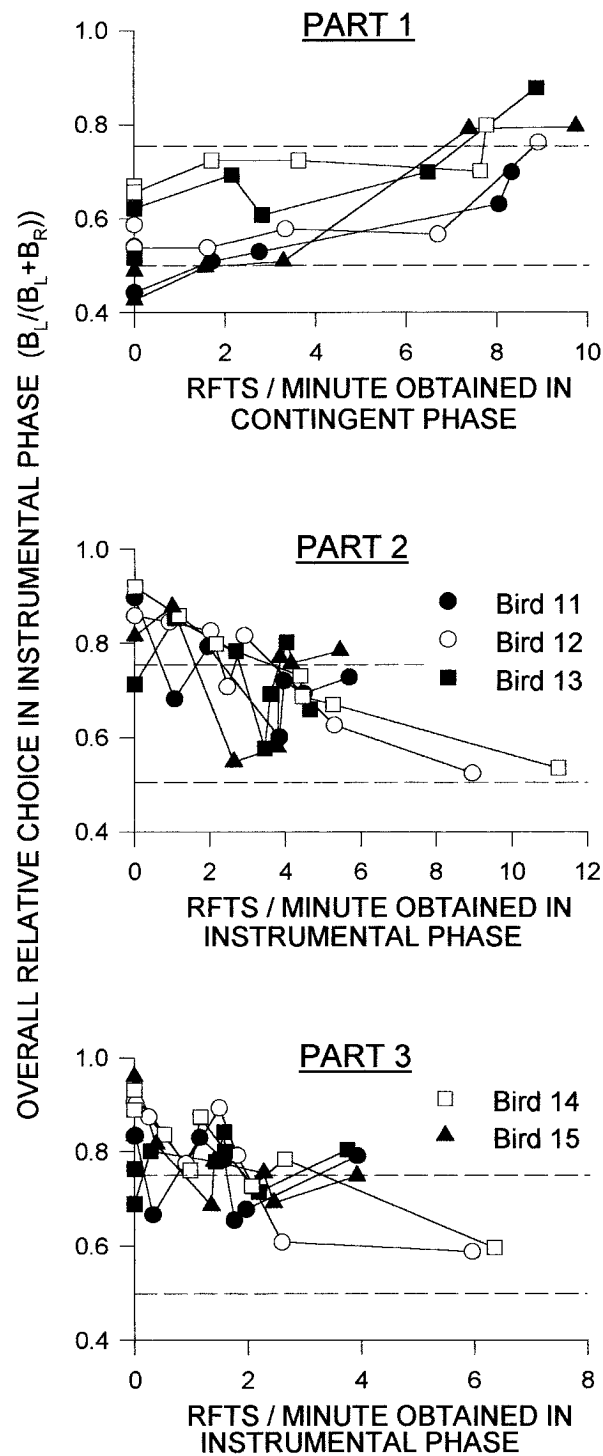
Fig. 2. Overall relative frequencies of left-key responses in the instrumental phase in each condition of Part 1 as a function of the number of reinforcers per minute obtained in the contingent phase (top panel) and in each condition of Parts 2 and 3 (center and bottom panels, respectively) as a function of the number of reinforcers per minute obtained in the instrumental phase. Different symbols denote the data for individual subjects.

across conditions while the rate of reinforcement arranged in the contingent phase was varied. In the top panel of Figure 2, overall relative rates of pecking in Part 1 are therefore plotted as a function of the number of reinforcers per minute obtained in the contingent phase. In contrast, in Parts 2 and 3, reinforcer rates arranged in the contingent phase were held constant, and those arranged in the instrumental phase were varied. Thus, for Parts 2 and 3, relative rates of key pecking are shown as a function of the number of reinforcers per minute obtained in the instrumental phase. All three panels show that the rates of reinforcement obtained in either the contingent (Part 1) or the instrumental phase varied over a reasonable range across the conditions within each part. The Appendix shows that changes in the obtained rates of reinforcers in the contingent phase in Part 1 and the instrumental phase in Parts 2 and 3 were ordinally related to changes in the arranged rates of these reinforcers. However, a comparison between Table 1 and Figure 2 shows that all subjects generally obtained fewer reinforcers per minute than were arranged. For example, in Condition 2 (Part 1), in which 24 reinforcers per minute were arranged in the contingent phase, the mean number of reinforcers obtained was only 8.72. Similarly, in Condition 18 (Part 2), in which 36 reinforcers per minute were arranged in the instrumental phase, the mean number of reinforcers obtained was only 7.0. Furthermore, the rates of reinforcement obtained in the instrumental phase of Parts 2 and 3 often differed markedly across subjects.

Despite obtained rates of reinforcement varying over a smaller range than was intended, Figure 2 shows that relative rates of key pecking in the instrumental phase changed systematically across conditions in all three parts. In Part 1, the proportion of total pecks that were made to the left key generally increased as the rate of reinforcement obtained in the contingent phase increased. Thus, with the rate of reinforcement in the instrumental phase held constant, as the rate of reinforcement for exceeding response proportions of .75 in this phase increased, so too did overall relative rates of key pecking. This trend was statistically significant when data from individual subjects were submitted to a nonpara-

metric test for monotonic trend (Ferguson, 1971; $N = 5$ subjects, $k = 5$ conditions, $z = 3.83, p < .05$).

In Parts 2 and 3 (Figure 2), the proportion of responses that were made to the left key in the instrumental phase was often considerably higher than the .75 criterion and generally decreased as the rate of reinforcement obtained in the instrumental phase increased. Each of these trends was statistically significant when data from individual subjects were considered together and submitted to nonparametric tests for monotonic trend (Ferguson, 1971; Part 2: $N = 5$ subjects, $k = 7$ conditions, $z = 3.22$, $p < .05$; Part 3: $N = 5$ subjects, $k = 7$ conditions, $z = 2.55$, $p < .05$). However, it should be noted that this trend was weak for several individual subjects, and was considerably less clear than the increasing trend observed in Part 1. Nevertheless, this result suggests that when the rate of reinforcement obtained for exceeding the criterion was held constant, increasing the rate of reinforcement obtained in the instrumental phase caused overall relative choice to move progressively closer to the indifference [i.e., $B_L / (B_L + B_R) = .5$] predicted by strict matching to the relative rates of reinforcement.

For Parts 1 and 3, the data points in Figure 2 that represent choice proportions in conditions that were replications of earlier conditions (i.e., Conditions 20 and 21) are depicted as symbols disconnected from the lines that join other data points. The top panel shows that, across subjects, there were no systematic differences between the choice proportions in Conditions 1 and 20. Four of the 5 birds showed more extreme measures of choice in Condition 20 than in Condition 1. Furthermore, in only two cases (Birds 11 and 12) were choice proportions from Condition 20 more extreme than they were from the condition in which the next higher rate of reinforcement was obtained in the contingent phase (Condition 3). Similarly, in Part 3 (bottom panel), choice proportions from Condition 21 were neither consistently higher nor lower than choice proportions from Condition 15. Two of the 5 birds showed more extreme measures of choice in Condition 21 than in Condition 15.

Parts 2 and 3 both involved varying the rates of reinforcement obtained in the instrumental phase when the rate of reinforcement
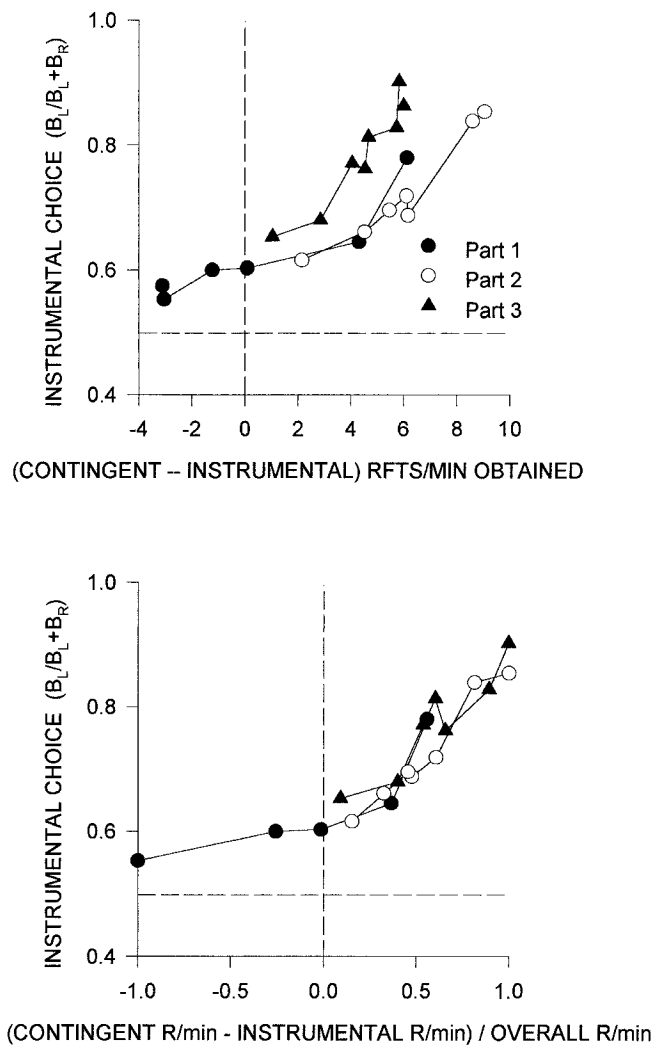
Fig. 3. Top panel: the mean relative rates of left-key responding across subjects for each condition as a function of the reinforcer rate obtained in the contingent phase, less the reinforcer rate obtained in the instrumental phase for that condition. Bottom panel: the same measures of overall choice as in the top panel, but now plotted against the difference between the obtained contingent-phase and instrumental-phase reinforcer rates, relative to the overall rate of reinforcement obtained in a session (i.e., the sum of contingent- and instrumental-phase obtained reinforcer rates).

in the contingent phase was held constant, but Part 3 arranged reinforcer rates in both phases that were approximately one third of those arranged in Part 2 (see Table 1). Thus, although the two parts arranged similar differences between the reinforcer rates in the two phases, they arranged different overall rates in both phases. Figure 3 examines the relation between overall instrumental choice and the difference between the reinforcer rates obtained in the two phases. The top panel of Figure 3 plots the mean relative rates

of left-key responding across subjects for each condition as a function of the reinforcer rate obtained in the contingent phase less the reinforcer rate obtained in the instrumental phase for that condition. The relations apparent here are representative of those seen for individual subjects. As expected, overall choice became progressively more biased to the left key as this reinforcer-rate difference increased in all three parts. However, the data clearly did not lie on a single function. Overall choice in Part 3 was higher than in Parts

1 and 2 at similar differences between contingent and instrumental reinforcer rates. This result suggests that the reinforcer rate in the instrumental phase in and of itself affected the degree to which choice could be biased by the contingencies arranged here.

The bottom panel of Figure 3 shows the same measures of overall choice as in the top panel, but now plotted against the difference between the obtained contingent-phase and instrumental-phase reinforcer rates relative to the overall rate of reinforcement obtained in a session (i.e., the sum of the obtained contingent- and instrumental-phase reinforcer rates). In contrast to the data shown in the top panel, the data now lie on a single function. Thus, the difference between reinforcer rates obtained in the contingent and instrumental phases, in the context of the overall rate of reinforcement obtained, seems to be a better predictor of overall choice than the simple difference per se.

Relative Frequency of Exceeding the Criterion in the Instrumental Phase

A second analysis of the present data examined the relation between rates of reinforcement obtained in either phase and the relative frequency with which subjects exceeded the criterion and obtained access to the contingent phase. Figure 4 shows these relative frequencies as a function of the number of reinforcers per minute obtained in the contingent phase in Part 1 and the reinforcers per minute obtained in the instrumental phase in Parts 2 and 3. These relative frequencies were obtained by calculating the proportion of instrumental windows that were followed by a contingent window and thus correspond to the obtained probability of exceeding the criterion in any one instrumental window.

Figure 4 shows evidence of trends that are similar to those observed in Figure 2. The top panel of Figure 4 shows that the relative frequency with which subjects exceeded the criterion in Part 1 generally increased as the reinforcer rate in the contingent phase increased. In addition, the center and bottom panels show that the relative frequency with which subjects exceeded the criterion in Parts 2 and 3 generally decreased as the reinforcer rate in the instrumental phase increased. All three of these trends were statistically significant when nonparametric tests for monotonic

trend (Ferguson, 1971) were conducted on individual-subject data (Part 1: $N = 5$ subjects, $k = 5$ conditions, $z = 4.05$, $p < .05$; Part 2: $N = 5$ subjects, $k = 7$ conditions, $z = 3.63$, $p < .05$; Part 3: $N = 5$ subjects, $k = 7$ conditions, $z = 3.09$, $p < .05$). Thus, systematic changes in the relative frequency with which subjects exceeded the criterion and obtained access to the contingent phase accompanied the systematic changes seen in overall measures of relative choice (Figure 2) as obtained rates of reinforcement varied across all three parts of the experiment.

Relative Frequency of Response Proportions in the Instrumental Phase

Given evidence of systematic changes in overall measures of instrumental choice (Figure 2), a further question posed in the present experiment concerns the nature of these changes. Specifically, we were interested in how instrumental choice at a more molecular level changed with variations in the instrumental and contingent reinforcer rates. Therefore, a further analysis of instrumental choice was conducted by examining the relative frequency with which subjects emitted various response proportions in the instrumental phase across the conditions of Parts 1, 2, and 3. Figure 5 presents the results of this analysis. Here, the relative frequency with which subjects emitted response proportions of 0 to .05, .051 to .1, .101 to .15, and so forth (in bins of .05) have been plotted separately for each condition of Parts 1, 2, and 3. In the interests of conserving space, only the mean data are shown here. The mean rates of reinforcement in either the contingent phase (Part 1) or the instrumental phase (Parts 2 and 3) that were obtained in each condition are shown in the legends of each panel.

The trends apparent in Figure 5 were representative of the trends apparent in individual subjects. In Part 1, the majority of instrumental phases in each condition involved responses to both keys. However, there was considerable overlap between the distributions from each condition, and the relative frequency of response-proportion bins between 0 and .95 was not related systematically to the reinforcer rate in the contingent phase. In Parts 2 and 3, a smaller proportion of instrumental phases involved responses to both keys, but again the distributions showing
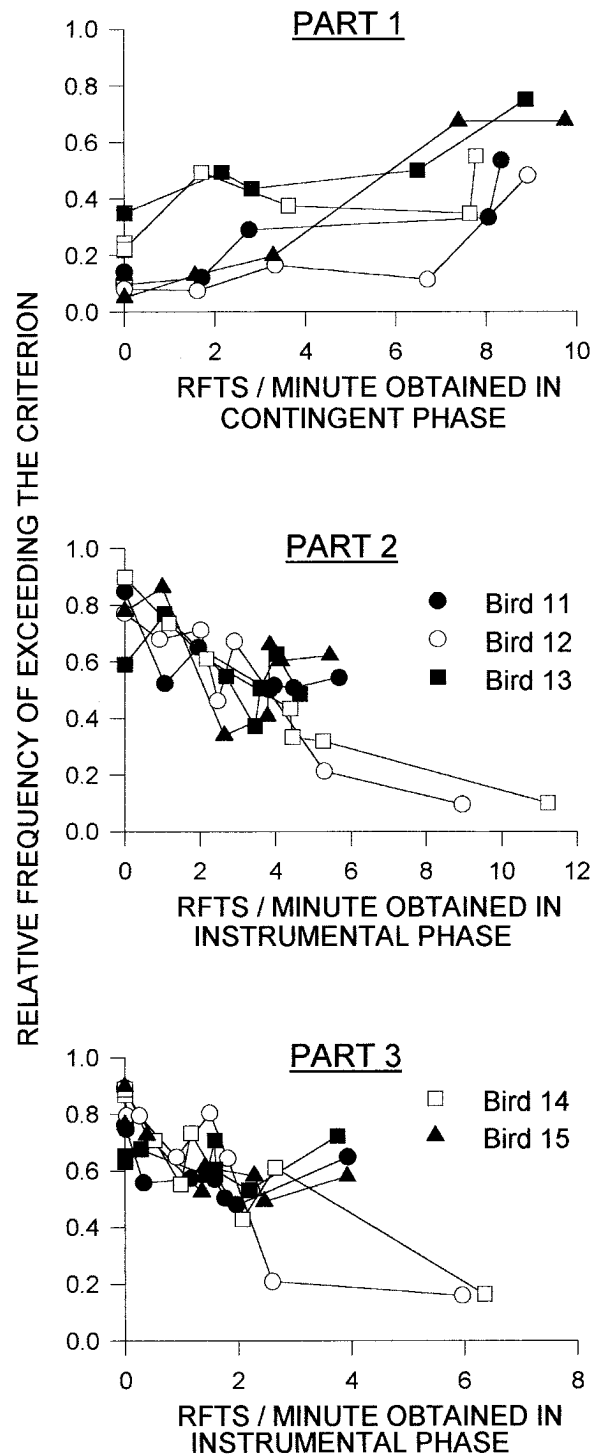
Fig. 4. The proportion of instrumental windows in which the criterion was exceeded in each condition of Part 1 as a function of the number of reinforcers per minute obtained in the contingent phase (top panel) and in each condition of Parts 2 and 3 (center and bottom panels, respectively) as a function of the number of reinforcers per minute obtained in the instrumental phase. Different symbols denote the data for individual subjects.
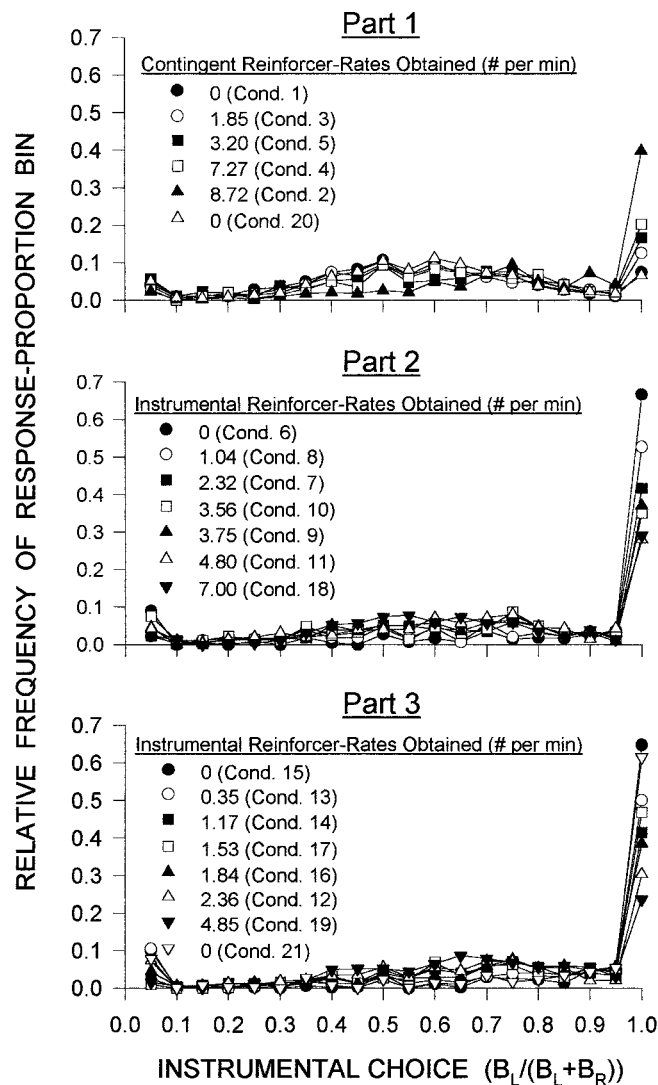
Fig. 5. The proportion of instrumental windows in which various relative left-key response rates were emitted in each condition of Parts 1, 2, and 3. These data have been calculated by summing the appropriate response and reinforcer frequencies across individual subjects. The mean rate of reinforcement obtained in that phase whose reinforcer rate varied over conditions within each part is shown for each condition alongside the symbol denoting data from that condition.

each condition overlapped considerably. In all parts, the greatest variation across conditions was observed in the relative frequency of instrumental phases in which the proportion of responses made to the left key was between .95 and 1. Furthermore, examination of the ordinal relations between conditions with respect to the obtained rates of reinforcement in either phase reveals systematic effects. The relative frequency of instrumental phases in which response proportions were between .95 and 1 increased systematically as the obtained rates of reinforcement in the contingent phase increased (Part 1), and as the obtained rates of reinforcement in the instrumental phase decreased (Parts 2 and 3). The significance of all three trends was confirmed by nonparametric tests for monotonic trends (Ferguson, 1971) conducted on individual-subject data (Part 1: $N = 5$ subjects, $k = 5$ conditions, $z = 4.05$, $p < .05$; Part 2: $N = 5$ subjects, $k = 7$ conditions, $z = 3.76$, $p < .05$; Part 3: $N = 5$ subjects, $k = 7$ conditions, $z = 3.49$, $p < .05$).
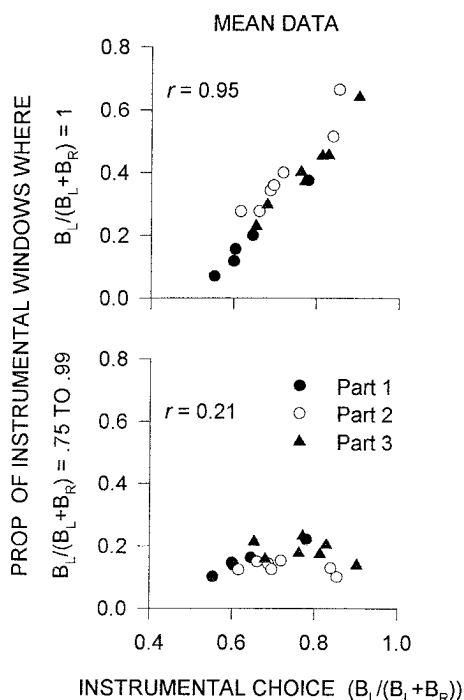
Fig. 6. The proportion of instrumental windows in which responding was exclusive to the left key (top panel) and in which relative rates of left-key responses were between .75 and .99 (bottom panel) as a function of overall measures of relative rates of responding to the left key. These data have been calculated by summing the appropriate response and reinforcer frequencies across individual subjects. See text for further explanation.

Figure 6 summarizes the relation between molar and molecular measures of choice that was observed in the present data. The top panel shows the mean proportion of instrumental windows in which responding was exclusive to the left key $[B_L/(B_L + B_R) = 1]$ as a function of the mean overall relative choice in each condition. The bottom panel shows the mean proportion of instrumental windows in which relative choice was between .75 and .99 as a function of the same overall measures of relative choice. The effects apparent in this figure directly support those that could partly be inferred from Figure 5. In all three parts, changes in overall measures of choice were correlated strongly with changes in the relative frequency with which subjects responded exclusively to the left key (top panel, $r = .95$), but correlated relatively weakly with changes in the relative frequency of windows involving choices of between .75 and

.99 (bottom panel, $r = .21$). Similar analyses of individual-subject data confirmed the generality of these results. The correlation between overall choice and the relative frequency of exclusive windows was significantly above zero ($p < .05$) for all birds except Bird 13. In contrast, the correlation between overall choice and the relative frequency of windows in which choice was between .75 and .99 was significantly above zero only for Birds 12 and 16. Furthermore, in the two cases in which both correlations were statistically significant, the correlation between overall choice and the relative frequency of windows in which responding was exclusive to the left key was higher than the correlation between overall choice and the relative frequency of windows in which relative choice was between .75 and .99. Thus, although access to the contingent phase required that relative choice $[B_L/(B_L + B_R)]$ equal or exceed .75, this contingency was effective in changing overall choice mainly by changing the relative frequency with which subjects responded exclusively to the left key.

Figure 7 examines further the effects of the overall reinforcer-rate contingencies on patterns of responding during the instrumental phase. These data represent the means over individual subjects but are similar to those evident for each individual in each condition.

Consider first the differences between the aggregate mean number of responses across the two types of instrumental phases. The left column shows that approximately equal numbers of left- and right-key responses were made during instrumental phases in which the criterion was not exceeded. Thus, although Figure 5 shows that only a small proportion of instrumental windows involved equal numbers of left- and right-key responses, when the responses in these windows were summed there was no clear evidence for choice being biased to the left key. In contrast, the right set of graphs reconfirms that subjects often responded exclusively to the left key during instrumental phases in which the criterion was exceeded.

Figure 7 shows also that the distribution of responses throughout either type of instrumental phase was remarkably similar across conditions. During phases in which the criterion was not exceeded, subjects began by emitting more right-key than left-key re-
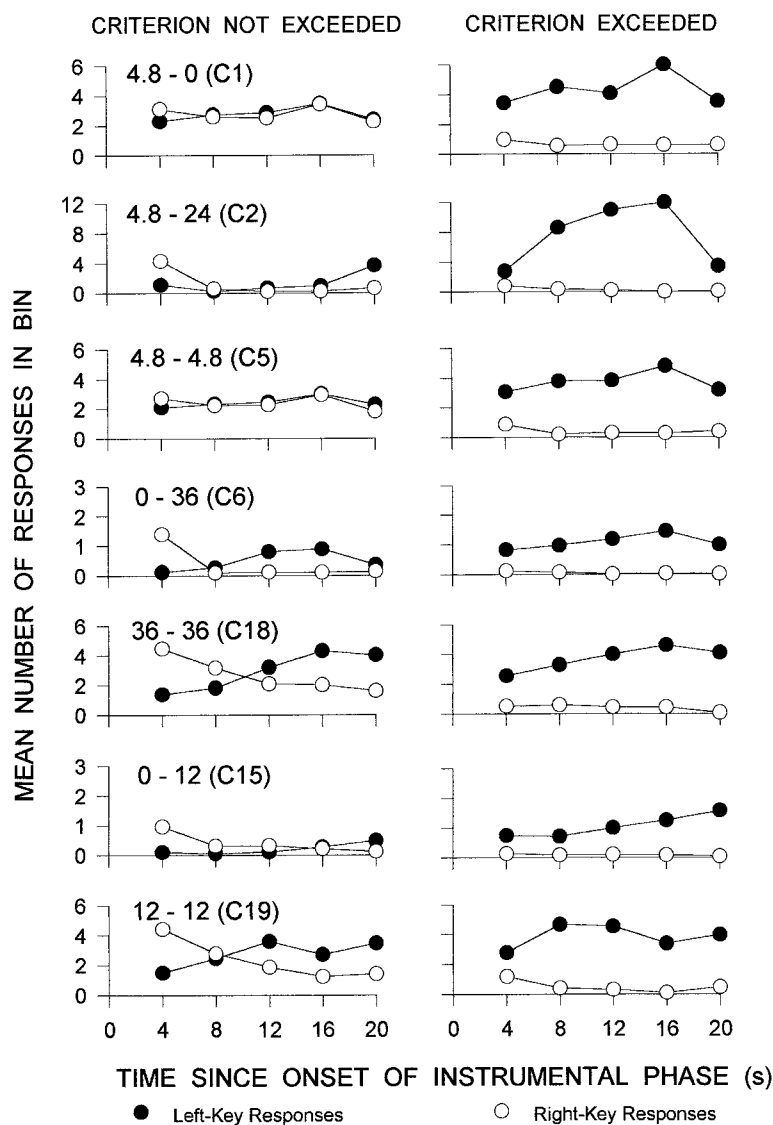
Fig. 7. The mean number of responses made to the left and right keys during successive 4-s bins of the instrumental phase. The left column of graphs present data from instrumental phases in which the criterion was not exceeded, whereas the right column of graphs present data from phases in which the criterion was exceeded. These data represent the means over individual subjects and come only from those conditions that produced the most and least extreme overall relative rates of responding (see Figure 2).

sponses, but shifted to more left-key than right-key responses by the end of the interval. (This pattern of responding may well reflect different momentary probabilities of left- and right-key reinforcers and the effects on these probabilities of holding arranged reinforcers across successive instrumental phases.) In contrast, during phases in which the criterion was exceeded, subjects responded at a generally constant rate to the left key, with little

or no evidence of the acceleration that is typical of fixed-interval schedule responding (Ferster & Skinner, 1957).

DISCUSSION

The principal results obtained in this experiment support the conclusions reached by Davison and Alsop (1991), Heyman and Tanz (1995), and Silberberg and Ziriax (1985):

Contingencies relating overall rates of reinforcement to measures of prior choice can, under certain conditions, affect this choice. In these studies, an increase in overall reinforcer rate followed the achievement of a criterion choice value. Both in these and in the present studies, relative choice in a concurrent VI VI schedule moved away from strict matching the concurrent-schedule reinforcer ratio and toward the value specified by the criterion.

The present experiment extended previous work by investigating the effects of absolute rates of reinforcement on the control of choice. Unlike all previous studies apart from Heyman and Tanz (1995), satisfaction of a criterion and a change in the overall rate of reinforcement were signaled by exteroceptive stimuli. When the rate of reinforcement in the instrumental phase was held constant (Part 1), relative choice in the instrumental phase increased toward, and beyond, the .75 criterion as the rate of reinforcement obtained in the contingent phase increased (Figure 2, top panel). Conversely, when the rate of reinforcement in the contingent phase was held constant (Parts 2 and 3), relative choice decreased toward .5 as the rate of reinforcement obtained in the instrumental phase increased (Figure 2, center and bottom panels). These results suggest that the overall rates of reinforcement obtained during the window over which choice is measured (instrumental phase here) and the window over which these rates are dependent on prior choice (contingent phase here) combined to determine the degree to which choice can be controlled by overall reinforcer rates. The bottom panel of Figure 3 showed that relative choice in the instrumental phase was best described as a linear function of the gain in overall reinforcer rates for exceeding the criterion, relative to overall reinforcer rates obtained in a session.

The relation between relative choice and overall rates of reinforcement seen in the present study may account, partially at least, for the conflicting results that have been reported in earlier studies of this type. Indeed, those studies that reported control of choice arranged changes in overall reinforcer rates that were considerably larger than those arranged in studies that failed to find evidence for such control. At the two extremes, Davison and Alsop (1991) arranged a 54-fold increase in overall reinforcer rates if relative choice exceeded a criterion, whereas Davison and Kerr (1989) arranged only a twofold increase if relative choice changed from exclusive (0 or 1) to indifferent (.5). Furthermore, given that the effectiveness of such contingencies will depend on the reinforcer rates actually obtained, reinforcer-rate changes in the two studies that failed to find evidence of control may also have been attenuated by their use of feedback functions to change overall reinforcer rates in a relatively continuous manner.

It is noteworthy that this argument also predicts the reported effects of window duration on the control of choice by overall reinforcer rates (Davison & Alsop, 1991; Silberberg & Ziriax, 1985). Both sets of authors reported that choice was affected by the same contingent change in overall reinforcer rates only when window durations were relatively short. It is quite feasible that window duration could affect the discriminability between, and differential reinforcement from, a consequential change in reinforcer rates. Consider, for example, a case in which window durations were 20 s and the schedules operating in the instrumental phase each arranged an average of one reinforcer per presentation of that phase (concurrent VI 20 s VI 20 s), whereas those operating in the contingent phase arranged an average of two reinforcers per presentation (concurrent VI 10 s VI 10 s). With such a combination of schedules and window duration, one might observe numerous occasions when, despite satisfaction of the criterion and a change in the arranged overall reinforcer rates, the number of reinforcers actually obtained in the windows prior to and after the change did not differ. Clearly, the more frequently this happens, the weaker will be the behavioral effect of the contingency.

In addition to investigating the effects of reinforcer rates on the control of choice, the present experiment also sought to identify how such contingencies changed choice behavior at a more molecular level. The results of these analyses lead to the same conclusion arrived at by Heyman and Tanz (1995). In the present study, access to the contingent phase required that relative choice $[B_{L}/(B_{L} + B_{R})]$ equal or exceed .75. Numerous combinations

of left- and right-key responses could have satisfied this contingency. However, Figures 5, 6, and 7 show that this contingency changed overall choice mainly by changing the relative frequency of only one sequence of responses, that of responding exclusively to the left key. Heyman and Tanz arranged contingencies in which the nth response was reinforced if it produced a relative measure of choice that equaled or exceeded a specific criterion when all n responses were considered (Experiment 2). When they analyzed the frequency with which their subjects emitted various numbers of consecutive right-key responses, they found clear evidence of sequential dependencies between responses (see their Figures 5a, 5b, and 5c, and associated algebraic proof). Heyman and Tanz subsequently argued that the control of choice by overall rates of reinforcement was mediated by molecular processes (i.e., the strengthening of sequences of left and right responses) rather than molar processes (i.e., the strengthening of a relative rate of responding). Clearly, the present data are in accord with this conclusion.

The appearance of stereotypic patterns of responding during the instrumental phase of the present study raises the possibility that our contingencies shaped a new unit of behavior or response class (i.e., responding exclusively to the left key). Indeed, the emergence of invariant patterns in the temporal organization of behavior has often been reported when molar measures of reinforcement are related to more molar aspects of responding (see Shimp, 1979, for a review). However, it is no simple matter to ascribe function to stereotyped patterns of responding, and numerous authors have discussed the criteria to determine whether any particular measurable aspect of behavior consitutes a functional unit of behavior (e.g., Branch, 1977; Shimp, 1979; Zeiler, 1977). The criterion common to all these approaches has been that of *conditionability*; that is, some pattern or sequence of responding is a viable functional unit if the probability with which that behavior occurs can be seen to be affected by its consequences. This criterion has also often appeared as a defining feature of the behavioral unit referred to as an *operant class* (e.g., Schick, 1971). The question of interest in the present analysis then can be re-

phrased: Did responding exclusively to the left key during an instrumental-phase window emerge as an operant class whose frequency was related to its consequences? If so, then this new operant might reasonably be considered to be a complex operant (Morse, 1966) because it was of an order higher than individual left- and right-key pecks.

Clearly, if one were to use only the criterion of conditionability, the answer to this question must be affirmative, because the frequency of occasions on which responding was exclusively to the left key $[B_L / (B_L + B_R) = 1]$ increased systematically as the relative gain in reinforcer rates for satisfying the contingency (and, therefore, the gain in reinforcer rates for responding exclusively) increased. Furthermore, if exclusive periods of responding were not instances of an operant class and reflected only the summation of the constituent smaller units (i.e., left-key pecks), one might reasonably expect to observe a scallop in the temporal pattern of key pecking during these periods, and we did not (see Figure 7).

Above, we argued that the effectiveness of contingencies that relate choice to overall reinforcer rates depended on the relative gain in overall rates of reinforcement that was obtained following satisfaction of the contingency. However, the treatment of exclusive periods of left-key responding as an emergent unit of behavior suggests an alternative way of conceptualizing the control by reinforcer parameters observed in this study. This alternative follows from an argument made by Herrnstein (1982). Herrnstein predicted that evidence for the control of choice by overall rates of reinforcement would entail the emergence of new units of behavior that, when correctly identified, would obey the matching principle (Herrnstein, 1961). In terms of the present results, this argument implies that subjects may have chosen between emitting either of the complex operants (i.e., responding exclusively to the left key, or responding to both keys in accordance with the relative rate of reinforcement currently available), and that the relative frequency of either operant might have been controlled by the relative frequency with which that operant was reinforced. In other words, the varying degrees of control over choice seen here might have reflected some varying relative rate at

which either of the two complex operants was reinforced. Heyman and Tanz (1995) speculated that a similar process was operating in their experiments. But how are we to construe the reinforcement of either complex operant (and, thereby, a relative rate of reinforcement) when reinforcers were only ever temporally contiguous with left- and right-key pecks, the hypothetical "first-order operants," and responding exclusively to the left key was never itself directly reinforced?

A solution to this problem might be offered by adopting Baum's definition of reinforcement as situation transition (Baum, 1973), and abandoning an insistence of behavior–reinforcer temporal contiguity in the definition of a behavioral unit or operant (Baum, 1973; Hawkes & Shimp, 1975; Schwartz, 1986). Baum argued that "reinforcement can be viewed as a transition from a lower-valued situation to a higher-valued situation" (p. 151). According to this definition, reinforcement could have operated at two levels of analysis in the present experiment. At the lower level, in all conditions, left- and right-key pecks were being reinforced by transitions from keylight situations to food access, because these transitions always required either response. At the higher level of analysis, and in only some conditions, extended periods of left-key pecking in the instrumental phase could have been reinforced by transitions from signaled periods of low reinforcer rates (the instrumental phase signaled by yellow keylights) to other signaled periods of higher rates (the contingent phase signaled by red keylights). By this definition, therefore, the relative rate of reinforcers for left-key pecks was clearly always .5, because the same frequency of transitions into equally valued situations was arranged for left- and right-key pecks. The relative rate of reinforcement for either complex operant, on the other hand, will have varied across conditions as the frequency of transitions from instrumental to contingent phases varied. However, the frequency of these transitions was uncontrolled and depended on the frequency with which choice exceeded the criterion, the very aspect of behavior that we are trying to predict. Moreover, by varying the reinforcer rates in the instrumental and contingent phases, and thus the relative "value" of either the instrumental or contingent phases, variations in

the relative rate of reinforcement were confounded with variations in the relative magnitude of this reinforcement. Both of these features of the present procedure make any formal and quantitative assessment of Herrnstein's (1982) prediction very difficult. Nevertheless, it remains possible that responding exclusively to the left key did emerge as a behavioral unit, and that the relative frequency of this unit "matched" the relative rate or magnitude of its reinforcement.

To summarize, the present experiment demonstrated how certain aspects of reinforcement affect the degree to which choice can be modified by contingencies that relate overall rates of reinforcement to values of some prior choice. However, these effects were demonstrated in a procedure that signaled reinforcer-rate changes explicitly, that arranged only one specific criterion, and that always arranged equal relative rates of reinforcement for the two constituent responses. Thus, the extent to which the results obtained here might apply to other slightly different preparations is unclear and awaits further research. This research might well address the effects of varying the criterion specified in the contingencies, the band width of this criterion, the relative rate of reinforcement in the instrumental phase, and any interaction between this relative reinforcer rate and the criterion. Such systematic replications would serve either to limit or to extend the generality of what was found here.

A particular feature of the present data that warrants further investigation is the molecular structure of the change in overall choice. The identification of invariant patterns of responding, and systematic changes in the frequency of these patterns, was compatible with an account that supposed a choice between higher order operants and the control of this choice by higher order reinforcement parameters. This interpretation must, however, be considered only speculative, because the results that support it might also be described by a model that assumed left- and right-key pecks remained the fundamental operants, and that predicted orderly changes in interchangeover times with variations in the overall rates of reinforcement. Whichever account one adopts, there can be little doubt that some relative allocation of responding, or relative choice, is indeed a conditionable unit of

behavior whose frequency is subject to reinforcer parameters that determine the probability of operants in general.

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APPENDIX

The number of entries into the instrumental and contingent phases, the number of responses made to the left and right keys (B_L and B_R, respectively), the time spent responding on the left and right keys (T_L and T_R, respectively), and the number of reinforcers obtained for responses to the left and right keys (R_L and R_R, respectively), during the instrumental and contingent phases of each condition. These data represent the sums of the last five sessions of each condition.

| | | Instrumental phase | | | | | | | Contingent phase | | | | | |
| | Con- | En- | | | | | | | En- | | | | | | |
Bird	dition	tries	B_L	B_R	T_L	T_R	R_L	R_R	tries	B_L	B_R	T_L	T_R	R_L	R_R
11	1	207	1,416	1,779	1,331	1,418	110	90	20	93	86	125	88	0	0
	2	84	627	270	948	308	37	38	45	401	535	247	392	57	68
	3	173	1,257	1,211	1,149	1,099	88	100	21	89	240	92	221	9	3
	4	114	885	518	959	526	50	48	38	312	466	287	381	60	42
	5	169	1,021	910	1,175	1,043	81	74	49	317	498	321	445	24	21
	6	86	175	20	1,872	631	0	0	73	1,139	580	720	318	126	74
	7	86	639	167	1,209	149	35	21	56	676	516	431	313	83	61
	8	107	401	187	1,038	554	18	20	56	416	609	295	482	83	79
	9	66	557	217	627	320	53	34	34	291	431	173	319	61	52
	10	72	466	310	646	429	45	47	36	336	395	198	309	71	37
	11	71	621	275	678	363	56	50	36	282	465	187	363	44	50
	12	146	903	428	1,577	943	49	47	70	533	457	554	525	63	41
	13	174	375	188	1,407	1,565	7	12	97	934	1,140	678	859	90	91
	14	138	1,067	219	1,675	243	28	25	79	830	969	534	693	80	67
	15	150	252	50	1,882	2,683	0	0	112	1,255	1,003	1,023	781	103	96
	16	131	792	419	1,387	764	35	42	66	521	591	420	515	62	61
	17	123	802	222	1,520	225	33	32	70	630	844	458	598	67	68
	18	57	551	206	675	151	44	64	31	208	444	157	305	46	46
	19	77	724	191	1,079	135	45	56	50	289	644	234	516	48	51
	20	211	1,698	1,442	1,611	1,438	92	108	30	143	164	250	172	0	0
	21	143	274	55	1,498	2,270	0	0	109	1,150	1,158	823	887	107	93
12	1	183	4,115	3,521	1,679	1,252	101	99	15	86	359	44	157	0	0
	2	83	2,500	781	1,106	268	49	32	40	939	857	306	310	60	59
	3	173	3,918	3,369	1,570	1,172	102	91	13	288	344	92	124	5	2
	4	149	3,489	2,661	1,386	930	77	85	17	339	419	118	180	21	17
	5	163	3,152	2,306	1,618	887	81	89	27	225	755	119	341	14	16
	6	92	319	53	1,455	279	0	0	71	1,759	1,191	627	477	114	86
	7	73	815	172	1,066	109	26	23	52	932	916	402	379	80	71
	8	78	1,276	234	1,205	115	11	13	53	1,084	926	410	354	86	90
	9	64	1,258	284	987	127	30	32	43	1,003	825	371	254	86	52
	10	78	1,443	594	1,034	231	31	33	36	965	533	358	194	91	45
	11	80	2,090	1,251	883	369	77	64	17	457	296	153	96	41	18
	12	158	3,909	2,525	1,525	932	73	64	33	869	695	311	229	37	26
	13	117	1,866	270	1,764	105	6	4	93	2,215	1,777	783	643	101	89
	14	125	1,440	418	1,776	234	20	18	81	1,959	2,185	641	629	75	87
	15	117	1,142	125	1,652	111	0	0	93	2,678	1,797	930	557	96	103
	16	102	2,040	244	1,573	109	20	31	82	1,888	1,851	640	588	82	67
	17	104	2,496	654	1,444	289	32	31	67	1,444	1,735	426	595	64	73
	18	63	1,570	1,429	508	433	100	88	6	80	198	27	75	4	8
	19	88	2,306	1,613	845	533	80	95	14	328	368	107	122	11	14
	20	179	5,346	3,764	1,586	1,248	110	90	20	218	637	82	248	0	0
	21	104	1,311	136	1,312	140	0	0	93	2,312	1,932	750	717	99	101
13	1	217	3,083	1,877	1,945	1,160	105	95	76	142	544	185	426	0	0
	2	68	545	76	983	29	25	24	51	635	945	310	439	79	72
	3	164	2,050	909	1,730	783	68	74	81	413	1,269	367	757	27	31
	4	100	1,055	455	1,033	514	40	52	50	411	828	387	458	66	42
	5	147	1,423	917	1,511	644	73	67	64	357	898	420	506	33	27
	6	110	298	120	1,342	875	0	0	65	581	1,003	347	508	112	88
	7	84	763	211	1,053	429	40	35	46	355	832	211	467	78	47

APPENDIX

(*Continued*)

Bird	Con-dition	En-tries	B_L	B_R	T_L	T_R	R_L	R_R	En-tries	B_L	B_R	T_L	T_R	R_L	R_R
				Instrumental phase							Contingent phase				
	8	65	407	70	863	69	11	12	50	608	1,037	297	449	88	89
	9	81	673	299	948	463	56	41	41	340	735	261	319	52	51
	10	94	739	544	953	563	43	65	35	216	619	235	327	51	41
	11	66	657	339	698	287	57	45	32	241	630	162	293	54	44
	12	126	905	360	2,272	421	51	41	67	470	1,140	580	516	50	58
	13	139	467	116	1,894	175	10	3	94	1,376	1,571	719	730	95	92
	14	130	1,115	317	1,752	438	35	27	76	648	1,368	542	654	74	64
	15	179	266	120	3,269	2,733	0	0	117	1,689	1,984	1,066	840	97	103
	16	106	919	172	1,584	72	23	33	75	876	1,433	553	648	83	61
	17	126	1,004	251	1,818	146	34	33	76	878	1,573	555	669	63	70
	18	59	408	101	863	60	42	37	37	302	600	183	283	54	67
	19	72	765	187	1,001	82	37	53	52	464	1,338	303	522	51	59
	20	210	2,672	2,504	1,427	1,714	96	103	46	126	734	162	469	0	0
	21	157	431	134	2,217	908	0	0	99	1,747	1,854	750	786	92	108
14	1	185	4,491	2,357	1,776	1,293	93	107	41	575	371	292	254	0	0
	2	89	2,411	606	1,202	287	42	31	49	1,056	725	416	334	66	61
	3	160	4,799	1,833	1,716	923	76	79	79	1,567	1,269	642	699	26	19
	4	95	2,877	1,228	1,049	549	68	48	33	731	528	308	256	44	40
	5	128	3,428	1,304	1,451	615	77	65	48	1,028	726	458	330	29	29
	6	69	895	78	1,082	63	0	0	62	1,358	818	555	362	118	82
	7	72	1,723	433	1,012	202	22	30	44	1,182	615	426	255	98	50
	8	72	1,526	250	1,070	152	12	16	53	989	669	459	360	96	76
	9	75	1,837	838	763	345	47	64	25	504	293	232	146	57	32
	10	76	1,958	720	922	326	49	62	33	617	441	289	216	54	35
	11	72	1,709	841	752	384	72	54	23	448	250	232	106	51	23
	12	95	3,031	834	1,134	398	48	36	58	1,242	850	523	439	62	54
	13	120	2,111	413	1,783	234	10	11	85	1,868	1,292	787	598	88	91
	14	143	2,842	898	1,811	551	23	24	79	1,683	1,149	750	506	76	77
	15	116	1,330	99	1,818	91	0	0	103	2,484	1,326	1,055	623	107	93
	16	126	3,372	1,265	1,449	645	44	43	54	1,184	860	481	404	53	60
	17	90	2,410	350	1,459	166	18	17	66	1,617	1,184	605	482	91	74
	18	50	874	760	382	331	82	105	5	92	85	41	41	6	7
	19	85	1,918	1,300	817	510	94	86	14	329	247	131	98	12	8
	20	176	5,040	2,494	1,815	1,105	95	105	43	674	475	377	301	0	0
	21	113	1,605	200	1,729	159	0	0	98	2,192	1,747	849	741	93	107
15	1	194	1,947	2,613	1,472	1,653	109	91	10	49	203	30	94	0	0
	2	65	893	229	811	184	34	23	44	513	1,034	284	414	73	70
	3	178	1,994	2,021	1,451	1,399	96	92	23	81	691	68	340	5	7
	4	83	986	260	943	320	34	28	56	600	1,390	399	596	75	63
	5	161	1,633	1,576	1,395	1,175	79	86	32	203	1,076	148	411	16	19
	6	77	308	70	1,319	135	0	0	60	1,091	992	512	407	123	77
	7	115	1,278	1,052	1,244	622	54	47	39	511	936	241	366	54	45
	8	66	894	124	820	131	12	10	57	529	1,211	294	585	91	87
	9	81	865	628	970	360	47	55	33	407	900	194	324	60	38
	10	50	529	158	609	114	35	29	33	473	793	218	293	90	46
	11	58	559	179	783	124	40	40	35	399	985	217	358	67	53
	12	116	975	434	1,321	542	42	53	57	476	1,957	303	673	56	49
	13	117	849	192	1,447	281	5	10	85	854	1,689	611	809	93	92
	14	137	1,136	521	1,660	507	33	29	72	866	2,033	471	786	77	61
	15	97	1,068	45	1,175	133	0	0	87	1,200	2,230	649	841	103	97
	16	96	825	267	1,187	284	42	31	56	571	1,567	337	609	73	54
	17	111	1,309	371	1,349	332	28	24	68	559	1,805	392	730	64	84
	18	53	1,091	300	722	157	49	47	33	313	950	147	370	53	51
	19	81	1,311	439	1,050	279	52	54	47	476	1,128	313	461	44	50
	20	185	2,222	2,328	1,516	1,358	108	92	24	61	680	50	344	0	0
	21	131	1,194	238	1,761	219	0	0	100	1,305	2,063	737	913	102	98